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Team-based learning versus traditional teaching effect on pharmacy Students' Performance: A systematic review and Meta-Analysis

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ABSTRACT

Background: Several pharmacy schools have implemented team-based learning (TBL) in their curriculum worldwide. Yet, TBL's effectiveness compared to traditional teaching in improving students' outcomes in pharmacy education is yet to be assessed collectively. Thus, the aim of this meta-analysis is to compare the performance of pharmacy students following the implementation of team-based learning (TBL) in the pharmacy curriculum as opposed to traditional learning methods.
Methods: This systematic review and meta-analysis included studies that assessed students' performance after TBL was implemented in a pharmacy curriculum. Adhering to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines, the review conducted searches in Embase, MEDLINE, and Google Scholar until July 26, 2023.
Results: A total of 11 studies comparing TBL against traditional teaching methods and assessing students' performance were included. The pooled analysis, involving 2,400 students from 10 studies, demonstrated a mean difference (MD) in favor of TBL (MD = 2.27, 95 % CI [–0.85, 5.40]). However, notable heterogeneity was observed with an I^2 value of 82 %, and the observed difference did not reach statistical significance.
Conclusion: TBL exhibited enhanced student performance in pharmacy education compared to traditional teaching, although the difference was not statistically significant. The meta-analysis findings support the use of TBL in pharmacy education for various pharmacy courses (pharmaceutical and clinical sciences courses) and students at different levels. However, there is a need for more robust studies to comprehensively evaluate TBL, considering aspects such as students' performance and engagement, skills development, and satisfaction.

1. Introduction

Pharmacy education is undergoing a transformation from traditional teaching approaches to active learning strategies to promote self-directed and lifelong learning skills (Meng et al., 2019). The Accreditation Council for Pharmacy Education (ACPE) recommends implementing teaching methods that emphasize active learning, encourage students' accountability for self-directed learning, and foster collaborative learning (Accreditation Council for Pharmacy Education, 2016). In contemporary medical education, small-group learning methods, such as problem-based learning and team-based learning (TBL) play a predominant role (Trullàs et al., 2022). TBL, characterized as a learner-centered and active learning pedagogy, relies on students' active participation in small group discussions (Ofstad & Brunner, 2013; Parmelee et al., 2012). According to the Team-Based Learning™ Collaborative, TBL is defined as "an evidence-based collaborative learning teaching strategy designed around units of instruction, known as 'modules,' that are taught in a three-step cycle: preparation, in-class readiness assurance testing, and application-focused exercise (Team-Based Learning™ Collaborative,n.d).

The TBL strategy addresses various limitations of didactic learning, particularly the teacher-centered passive approach that tends to

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prioritize memorization over the development of problem-solving and analyzing skills (Bleske et al., 2016; Franklin et al., 2016; Grady, 2011; Kurup et al., 2017). By encouraging students to apply foundational knowledge through individual or team-based activities, TBL has proven effective in overcoming these drawbacks (Parmelee et al., 2012). This learning strategy has demonstrated positive impacts on students' learning outcomes, including knowledge acquisition, active participation, and the development of teamwork skills (Haidet et al., 2014). The increasing demand for health graduates capable of thriving in team-oriented environments has fueled the rapid growth of TBL utilization in health education (Interprofessional Education Collaborative, 2023). Pharmacy graduates must be able to solve problems, educate others, advocate for patients, and collaborate effectively as interprofessional team members (Accreditation Council for Pharmacy Education, 2016). Therefore, several pharmacy schools have implemented TBL in their courses (Bleske et al., 2016; Frame et al., 2016; Franklin et al., 2016; Grady, 2011). The incorporation of TBL into pharmacy education has resulted in enhanced student engagement, improved performance, increased confidence, and the refinement of communication and critical thinking skills (Bleske et al., 2016; Frame et al., 2016; Franklin et al., 2016; Ofstad & Brunner, 2013).

A previous systematic review that included studies that evaluated TBL in health professional education reported that implementing TBL improved scores on tests (Fatmi et al., 2013). However, there was inconsistency in the individual study results regarding students' knowledge and satisfaction after TBL use (Fatmi et al., 2013). Despite published experiences of TBL utilization in pharmacy education (Bleske et al., 2016; Frame et al., 2016; Franklin et al., 2016; Grady, 2011), there is a notable absence of a meta-analysis assessing the cumulative effectiveness of TBL in pharmacy education compared to traditional teaching. Therefore, the aim of this meta-analysis is to compare the performance of pharmacy students following the implementation of team-based learning (TBL) in the pharmacy curriculum as opposed to traditional learning methods.

2. Methods

In this systematic review and meta-analysis, we included studies that assessed students' performance after TBL was implemented in the pharmacy curriculum. The reporting of this review adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines for literature search reporting (Moher et al., 2015). Furthermore, the review was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO) under the identification number CRD42022341364.

2.1. Literature search

Our systematic search covered EMBASE and Medline via OVID, as well as Google Scholar, initially until July 26, 2023. We used the following MESH terms for the search: pharmacy or pharmaceutical* or pharmacy school* or pharmacy curriculum or pharmacy education and team-based learning.

Inclusion criteria comprised full-text articles in English that compared TBL in any course within the pharmacy curriculum to conventional teaching strategies. The studies needed to objectively assess students' performance, primarily through grading of course activities or exams, which served as our primary outcome measure. Exclusion criteria were applied to studies using GPA as the sole outcome, as it might encompass grades from courses where TBL was not implemented. Additionally, studies focusing on TBL's impact on students' perceptions, as well as assessments of student or faculty satisfaction or those utilizing subjective assessment methods, were excluded. Furthermore, studies in which TBL was implemented in training or interprofessional education activities were not considered. The main outcomes of interest were students' performance, as evaluated by their grades assessing knowledge or skills.

2.2. Data extraction and quality assessment

Two independent reviewers (G. K. and A. A.) screened potential studies and extracted data from eligible studies. During that stage, the reviewers maintained a blind review process with regard to author identities; however, institutions were not blinded if mentioned in the abstract. Disagreements about eligibility were resolved by consensus. The researchers selected relevant studies based on the title and abstract and then extracted relevant data. The extracted data were entered into a data extraction sheet to collect relevant data, which included the type of study, number of students (sample size), level of the students, the course that implemented TBL, the intervention that implemented TBL, study objectives, and students' outcomes related to the evaluation of students' knowledge and skills. We also assessed the quality of the studies and bias using the Joanna Briggs Institute (JBI) critical appraisal tools, depending on the type of study (Joanna Briggs Institute, 2020). We predetermined that studies were deemed "low" quality if they did not meet three or more JBI appraisal criteria. Studies were deemed "moderate" quality if they did not meet one to two JBI criteria and "good" quality if they met all JBI criteria. However, the quality of the studies did not affect their eligibility to be included in the review.

2.3. Statistical analysis

The primary outcome was the mean difference (MD) of students' performance scores. Random-effect models were used, as we assumed there would be differences across the included studies. The random-effects mean differences are presented with 95 % confidence intervals (95 % CIs). In addition, Cohen's d was used to compute the effect size of the difference between the means of the two groups. We analyzed all ten studies and then classified them based on the use of TBL, either in therapeutic or nontherapeutic courses. To investigate heterogeneity, we performed a visual inspection of the forest plots for the direction and magnitude of the effects and the degree of overlap between the confidence intervals. Furthermore, the *p*-value from the χ^2 test was calculated, and heterogeneity between studies was reported by means of I^2 statistic. R statistical software version 4.2.2 was used to pool the appropriate data and conduct the meta-analysis.

3. Results

The initial search screen yielded 271 articles based on the title and abstract, and three articles were found with a manual search. We identified 93 duplicates among these studies. A total of 178 articles were screened, and 157 did not meet the inclusion criteria. Thus, 21 full-text articles were assessed, but only 11 were included in the review. These studies were published between 2011 and 2022 within our study window. The remaining 10 articles were excluded according to the exclusion criteria described in the flow diagram in Fig. 1.

3.1. Study characteristics and quality assessment

All 11 included studies compared TBL with traditional teaching methods and assessed students' performance. Most of these were considered observational cohort studies, and only one by McCartney and Boschmans (2020) was a quasi-experimental study. The studies included pharmacy students from the first to the final years of pharmacy school. In these studies, courses that implemented TBL were physiology, pharmacotherapeutics, self-care, pharmaceutical calculation, and drug discovery and development courses. All study parties were unblinded in the studies because instructors deliberately utilized the teaching methods, and students consented to participate.

The characteristics of the studies and collected data are summarized in Table 1.

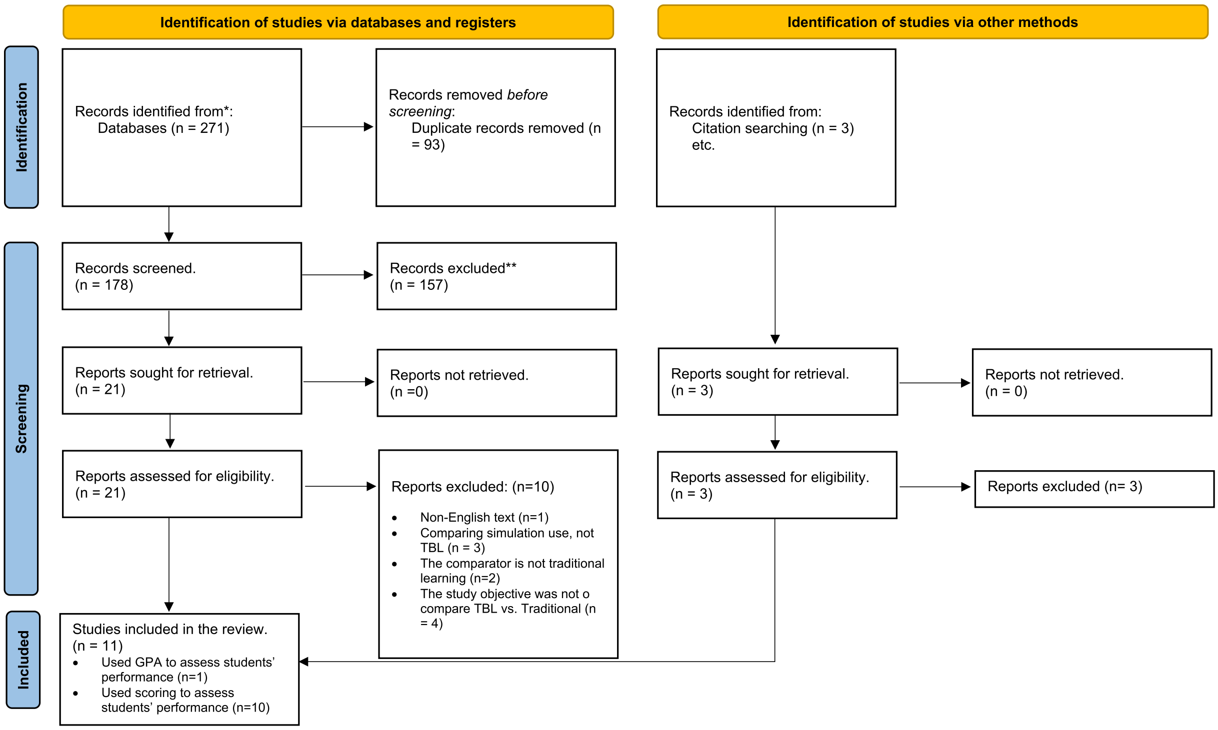

Fig. 1. Flow diagram of included studies. *From:* Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. https://doi.org/10.1136/bmj.n71. For more information, visit https://www.prisma-statement.org/.

According to the JBI critical appraisal tool for the nine cohort studies, only two articles were of moderate quality, those conducted by Muzyk et al. (2015) and Wilson et al. (2016). The remaining seven studies were of low quality because they did not identify confounding factors or manage confounders (Table 2). The quasi-experimental study by McCartney and Boschmans (2020) was deemed high quality, as shown in Table 3.

3.2. Study outcomes

3.2.1. Students' performance in TBL vs. Traditional teaching

Only 10 studies were pooled in the meta-analysis, as the study by Johnson et al. (2014) was not included because grades were reported alphabetically and not numerically. The 10 pooled studies included a total of 1,215 students in TBL and 1,185 students in traditional learning. However, three studies reported grade means without standard deviations (S.D.) (Bertsch et al., 2021; Tweddell, 2020; Wilson et al., 2016). Thus, for Bertsch et al. (2021) and Wilson et al. (2016), the standard deviation was imputed using the average standard deviation observed in other studies. Additionally, in the Tweddell (2020) study, the *p*-value was utilized for analysis.

The pooled effect size across the studies showed a non-significantly higher mean difference (MD) with TBL (MD = 2.27, 95 % CI [–0.85, 5.40]) with high heterogeneity (I^2 = 82 %) (see Fig. 2). At the same time, pooled effect size across the non-therapeutic course studies also showed a nonsignificant mean difference between TBL and traditional teaching (MD = 4.82, 95 % CI [–1.59, 11.24]), while the mean difference was lower in the therapeutic courses (MD = 0.34, 95 % CI [–3.50, 4.18]). However, the heterogeneity was lower between the therapeutic course studies (I^2 = 68 %) and the nontherapeutic courses (I^2 = 80 %). The mean effect size for the 10 studies was 0.44, indicating a positive effect of TBL on students' performance.

The results favoring TBL were mostly driven by Persky and Pollack (2011) and Twedell (2020) (MD = 8, 95 % CI [4.53, 11.47]; MD = 8.50, 95 % CI [4.47, 12.73], respectively). These studies implemented TBL in nontherapeutic courses. Moreover, in Kelly Orr et al. (2015), Gloudeman et al. (2018), Wilson et al. (2016), and McCartney and Boschmans (2020), the effect favored TBL but were not statistically significant, as presented in Fig. 2. In contrast, TBL did not show better results in the four remaining studies (Bertsch et al., 2021; Bleske et al., 2016; Cox et al., 2013; Muzyk et al., 2015).

A cohort study by Johnson et al. (2014) evaluated the use of TBL in a pharmacotherapeutic course after a change from lecture-based teaching. The comparison of students' final course grades spanned two years before the implementation of TBL and four years afterward, as detailed in the study by Johnson et al. (2014). Notably, the article presented students' grades alphabetically. In the Pharmacotherapeutic 190 course, among the 237 students in the lecture-based teaching group, 29 % received "A," 58 % received "B," and 12.6 % received "C". Conversely, of the total 477 in the TBL group, 30 % received "A," 62 % received "B," and 6 % received "C" (Johnson et al., 2014). In addition, in the Pharmacotherapeutic 192 course, more students received an "A" in the lecture-based format (34 %) than in the TBL format (27 %). In contrast, 60 % of the TBL students received "B," and 11 % received "C," compared to 47 % and 18 % of the lecture-based group. There were no numerical representations of the grades. Thus, the study results were not included in the pooled analysis (Johnson et al., 2014).

4. Discussion

This systematic review and meta-analysis examined studies that compared pharmacy students' performance in TBL versus traditional learning. Overall, the mean difference in students' grades was higher for TBL than traditional lecturing in most studies. However, the pooled analysis showed that the mean difference in students' grades was higher for TBL, but not statistically significant (MD = 2.27, 95 % CI [–0.85, 5.40]). Moreover, the mean effect size of 0.44 showed a medium positive effect of TBL on students' performance compared to traditional teaching.

The study trend toward better student performance with TBL was

Table 1
The Characteristics of Included Studies Comparing TBL to Traditional Teaching in Pharmacy Education.

#	Citation	Institution & Country	Pharmacy Course	Sample Size	Student Level	Intervention	Assessment Method	Outcomes
1	Persky and Pollack, 2011	Pharmacy school at the University of North Carolina, USA	Physiology	N = 277; TBL = 128, lecture = 149	P1	Modified team-based learning	Physiology Examination Scores	Knowledge and application
2	Cox et al., 2013	UNC Eshelman School of Pharmacy, Chapel Hill, NC, USA	Ambulatory care course	N = 80, Pre-TBL n = 9, Post-TBL 71	P3	TBL	Exam Questions; Final course grades	Knowledge and application
3	Bleske et al., 2016	College of Pharmacy, University of Michigan, USA	Pharmacotherapeutics "integrated"	N = 182; TBL n = 97, lecture-based, n = 85	P3, P2	TBL	Exam Questions	Recall of knowledge, application of knowledge, Overall score of essay
4	Johnson et al.,2014	Drake University College of Pharmacy and Health Sciences, Des Moines, Iowa USA	Pharmacotherapeutics	N = 684, TBL = 477 & Pre-TBL = 237	P3, P2	TBL	Final course grades	Knowledge, application, skills, analysis, and critically evaluate
5	Muzyk et al.,2015	Campbell University College of Pharmacy & Health Science (CPHS)	Pharmacotherapeutics	N = 205,TBL = 104, Didactic n = 101	P3	TBL	Test questions	Knowledge and application
6	Kelly Orr et al., 2015	College of Pharmacy, The University of Rhode Island, USA	Self-care course	N = 450; TBL = 250, Lecture = 200	Undocumented	TBL hybrid structure	Mean course grade	Knowledge, communications, professional skills, and teamwork
7	Wilson et al.,2016	Wingate University School of Pharmacy,Wingate, NC, USA	Self-care/OTC pharmacotherapy course.	N = 77; TBL 31, Traditional = 46	P2	TBL	Long-term retention through a quiz. Short-term retention; comparing performance on course exams	Knowledge retention
8	Gloudeman et al., 2018	Touro University California College of Pharmacy, CA, USA	Pharmaceutical calculation	N = 206; TBL = 102, Traditional n = 104	P1	TBL	Mean pharmaceutical calculation examination scores	Knowledge and application
9	Tweddell, 2020	University of Bradford, Bradford, UK	Consultation skills module	Pre-TBL = 173 post-TBL = 192	Undergraduate Master of Pharmacy (M. Pharm.)	TBL	Students examination results	Knowledge and application
10	McCartney and Boschmans, 2020	Nelson Mandela University (NMU), South Africa	Pharmacology and Therapeutics-4	Pre-TBL = 69, post-TBL = 104	Final year BPharm students	Modified team-based learning	Formative and summative assessment	Knowledge and application
11	Bertsch et al.,2021	Washington State University College of Pharmacy and Pharmaceutical Sciences	Drug Discovery and Development course	Pre-TBL = 121, TBL phase 1 = 126, TBL phase2 = 138	P2	TBL	The first attempt of the block competency test	Knowledge and application

P = pharmacy level; TBL = team-based learning; OTC = over the counter.

similar to previous meta-analyses in dental and medical education (Chen et al., 2018; Dong et al., 2022). A previous meta-analysis that compared lecture-based learning with TBL pedagogy in Chinese pharmacy education included 1271 students from 12 studies and found that pharmacy students showed significantly improved test scores in TBL compared to lecture-based teaching (SMD = 1.69, 95 % CI [1.10, 2.28], $p < 0.00001$) (Lang et al., 2019). This benefit of TBL in students' performance was observed in theory and experiment-oriented courses (Lang et al., 2019). Moreover, another meta-analysis evaluating the effect of TBL on knowledge outcomes reported an overall medium positive effect size of 0.55, resonating without effect size (0.44) (Swanson et al., 2019). However, only 8 out of 17 studies included in that meta-analysis included pharmacy students (Swanson et al., 2019).

TBL is an effective teaching approach for all healthcare disciplines, including medicine, pharmacy, dentistry, nursing, and other allied health (Fatmi et al., 2013; Joshi et al., 2022; Reimschisel et al., 2017). This approach has improved academic performance, clinical skills, and communication outcomes (Fatmi et al., 2013; Joshi et al., 2022; Reimschisel et al., 2017). The results of our analysis favoring TBL were mostly driven by Perskey and Pollak (2011) and Tweddell (2020). These studies reported a significant mean difference in students' scores favoring TBL in a physiology course for first-year pharmacy students and a consultation skills module for undergraduate Master of Pharmacy (Persky & Pollack, 2011; Tweddell, 2020). It is noteworthy that our pooled analysis utilized summative assessment scores that did not incorporate the TBL activity grades, such as the readiness assessments or team application grades. Although exam grades objectively measure students' performance, comparing the advantages of TBL versus lecture-based teaching based on student grades may be insufficient. The advantages of TBL typically go beyond knowledge and critical thinking. It also might improve students' interaction, self-assurance, and communication, which are not captured in the analysis.

TBL tends to be utilized more in therapeutic courses in pharmacy schools (Bleske et al., 2016; Johnson et al., 2014; McCartney &

Table 2
JBI Critical Appraisal of Cohort Studies.

JBI critical appraisal checklist for cohort studies	Perskey and Pollack, 2011	Cox et al., 2013	Bleske et al., 2016	Johnson et al., 2014	Muzyk et al., 2015	Kelly Orr et al., 2015	Wilson et al., 2016	Gloudeman et al., 2018	Tweddell, 2020	Bertsch et al., 2021
Were the two groups similar and recruited from the same population?	Unclear	Unclear	Unclear	Unclear	Yes	Unclear	Yes	Unclear	Unclear	Unclear
Were the exposures measured similarly to assign people to both exposed and unexposed groups?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the exposure measured in a valid and reliable way?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were confounding factors identified?	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	No
Were strategies to deal with confounding factors stated?	No	No	No	No	No	No	No	No	No	No
Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)?	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	Yes
Were the outcomes measured in a valid and reliable way?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Was the follow-up time reported and sufficient to be long enough for outcomes to occur?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was follow-up complete, and if not, were the reasons to loss to follow-up described and explored?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were strategies to address incomplete follow-up utilized?	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear
Was appropriate statistical analysis used?	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No

Table 3
JBI Critical appraisal of quasi-experimental study.

	McCartney and Boschmans, 2020
Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)?	Yes
Were the participants included in any comparisons similar?	Yes
Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Yes
Was there a control group?	Yes
Were there multiple measurements of the outcome both pre and post the intervention/exposure?	Yes
Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	Yes
Were the outcomes of participants included in any comparisons measured in the same way?	Yes
Were outcomes measured in a reliable way?	Yes
Was appropriate statistical analysis used?	Yes
Overall appraisal	**Good Quality**

Boschmans, 2020; Muzyk et al., 2015; Wilson et al., 2016). However, using TBL in these courses did not always show significantly better student performance with TBL. Interestingly, non-pharmacotherapy courses, such as pharmaceutical calculation, drug discovery, and development and skills modules, have also shown better student performance with TBL applications (Bertsch et al., 2021; Persky & Pollack, 2011; Tweddell, 2020). These findings suggest that TBL can be an effective teaching method for various pharmacy courses and student levels.

On the other hand, studies by Cox et al. (2013), Muzyk et al. (2015), and Bleske et al. (2016) favored traditional learning. That same trend has been observed in medical and dental education in China (Chen et al., 2018; Dong et al., 2022). The better student performance in the lecture-based group reported by Bleske et al. (2016) was attributed to the discrepancy in background knowledge (delivered in previous courses) between the two cohorts (TBL vs. lecture-based). These results were mostly observed in recall questions, not high-level application questions (Bleske et al., 2016). Similarly, Muzyk et al. (2015) made reservations about a direct comparison of TBL and lecture-based groups because of the variation in the assessment methods and assessment periods of the two groups Cox et al. (2013) also questioned the validity of the questions used to assess the students, especially as they were not intended for research purposes. Moreover, the limited number of students in the lecture-based group (n = 9) was much lower than the TBL group (n = 71), which could have skewed the results (Cox et al., 2013).

Apart from the meta-analysis that assessed TBL in Chinese pharmacy education (Lang et al., 2019), this study is the first to evaluate the effect of TBL on students' performance in pharmacy curricula globally. However, this analysis has several limitations. The first limitation is the low quality and unclear study design of the included studies. The second limitation is the high heterogeneity and variability among the studies, which may have affected the overall meta-analysis results. The third limitation is the variability in the assessment methods used in the studies. The fourth limitation is the limited number of studies that assessed students' performance objectively with TBL compared to traditional learning in pharmacy education; moreover, most of these studies were nonrandomized.

Despite the proven benefits of TBL in previous studies, the use of TBL in pharmacy education remains limited (Allen et al., 2013). One study reported that only 33 % of U.S. pharmacy schools' faculty are implementing TBL (Allen et al., 2013). We expect this rate to be even lower

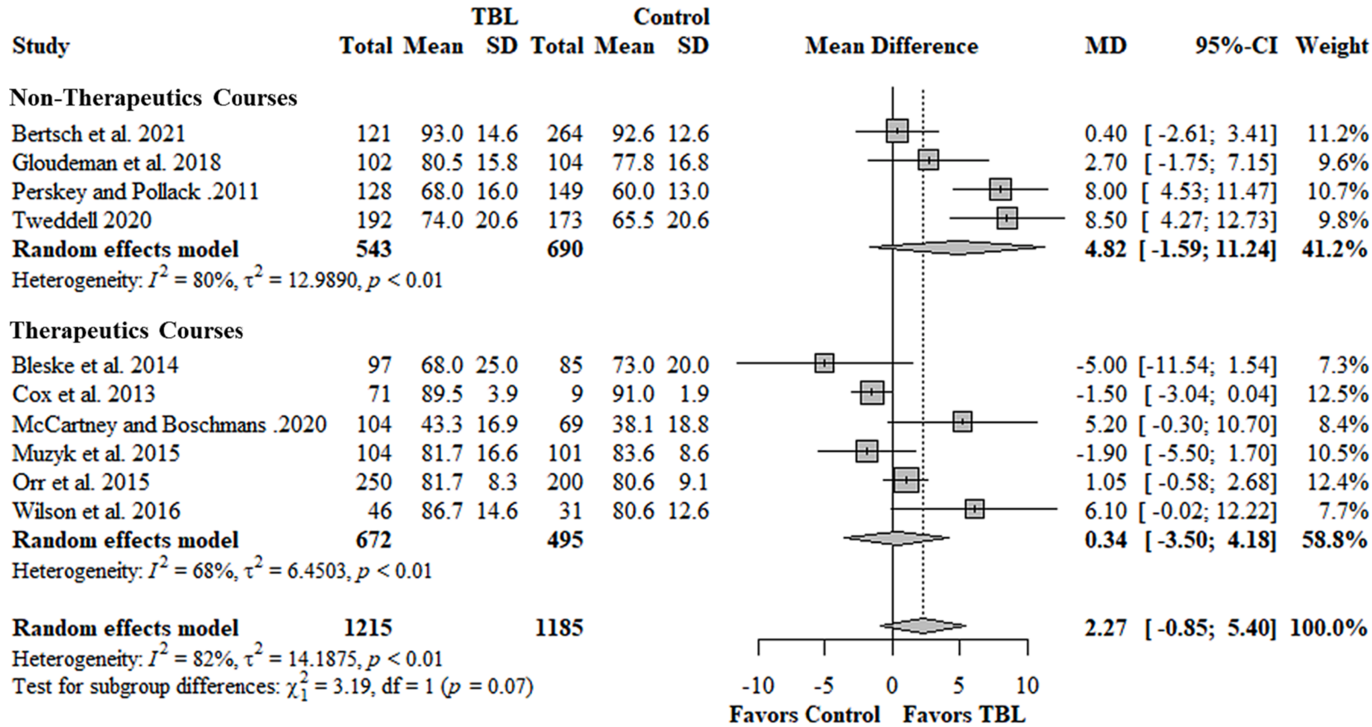

Fig. 2. Students' Performance Mean Difference in TBL vs. Traditional Teaching in Therapeutics and Non-therapeutics courses.

outside of the United States. The increase in student and faculty workloads with TBL may limit adaptation and satisfaction with TBL (Haidet et al., 2014). In addition, the lack of pharmacy education administration support and faculty resistance are some of the main barriers to implementing TBL (Allen et al., 2013). Our results help build a strong case for pharmacy administrators and faculty to adopt TBL in their curricula and educational practices. The meta-analysis provides evidence about the benefit of TBL using summative assessment. However, the additional benefits of TBL on student engagement and faculty satisfaction should not be ignored.

5. Conclusion

Compared to traditional teaching, TBL demonstrated better student performance in pharmacy education, although it was not statistically significant. The meta-analysis supports the use of TBL in various pharmacy courses and students at different levels. Although TBL's effectiveness in this meta-analysis was based on student performance, the advantages of TBL typically go beyond that. Nonetheless, more robust studies are needed to evaluate TBL in terms of students' performance and engagement, skills development, and satisfaction.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Accreditation Council for Pharmacy Education. (2016). *Accreditation standards and key elements for the professional program in pharmacy leading to the doctor of pharmacy degree*. https://www.acpe-accredit.org/pharmd-program-accreditation/.

Allen, R.E., Copeland, J., Franks, A.S., Karimi, R., McCollum, M., Riese, D.J., Lin, A.Y.F., 2013. Team-based learning in US colleges and schools of pharmacy. Am. J. Pharm. Educ. 77 (6) https://doi.org/10.5688/ajpe776115 (Article 115).

Bertsch, T.G., Denton, T.T., Perea, N.M., Ahmed, A., McKeirnan, K.C., 2021. Drug development and the process of transitioning to team-based learning in a qualitative way. Curr. Pharm. Teach. Learn. 13 (6), 723–728. https://doi.org/10.1016/j.cptl.2021.01.025.

Bleske, B.E., Remington, T.L., Wells, T.D., Klein, K.C., Guthrie, S.K., Tingen, J.M., Marshall, V.D., Dorsch, M.P., 2016. A randomized crossover comparison of team-based learning and lecture format on learning outcomes. Am. J. Pharm. Educ. 80 (7) https://doi.org/10.5688/ajpe807120 (Article 120).

Chen, M., Ni, C., Hu, Y., Wang, M., Liu, L., Ji, X., Chu, H., Wu, W., Lu, C., Wang, S., Wang, S., Zhao, L., Li, Z., Zhu, H., Wang, J., Xia, Y., Wang, X., 2018. Meta-analysis on the effectiveness of team-based learning on medical education in China. BMC Med. Educ. 18 (1) https://doi.org/10.1186/s12909-018-1179-1 (Article 77).

Cox, W.C., Kemp, D.W., Rodgers, P.T., 2013. Use of a team-based learning-influenced approach in an ambulatory care course. Curr. Pharm. Teach. Learn. 5 (5), 424–430. https://doi.org/10.1016/j.cptl.2013.03.001.

Dong, H., Guo, C., Zhou, L., Zhao, J., Wu, X., Zhang, X., Zhang, X., 2022. Effectiveness of case-based learning in chinese dental education: a systematic review and meta-analysis. BMJ Open 12 (2). https://doi.org/10.1136/bmjopen-2020-048497 (Article e048497).

Fatmi, M., Hartling, L., Hillier, T., Campbell, S., Oswald, A.E., 2013. The effectiveness of team-based learning on learning outcomes in health professions education: BEME Guide No. 30. Med. Teach. 35 (12), e1608–e1624. https://doi.org/10.3109/0142159X.2013.849802.

Frame, T.R., Gryka, R., Kiersma, M.E., Todt, A.L., Cailor, S.M., Chen, A.M.H., 2016. Student perceptions of and confidence in self-care course concepts using team-based learning. Am. J. Pharm. Educ. 80 (3) https://doi.org/10.5688/ajpe80346 (Article 46).

Franklin, A.S., Markowsky, S., De Leo, J., Normann, S., Black, E., 2016. Using team-based learning to teach a hybrid pharmacokinetics course online and in class. Am. J. Pharm. Educ. 80 (10) https://doi.org/10.5688/ajpe8010171 (Article 171).

Gloudeman, M.W., Shah-Manek, B., Wong, T.H., Vo, C., Ip, E.J., 2018. Use of condensed videos in a flipped classroom for pharmaceutical calculations: student perceptions and academic performance. Curr. Pharm. Teach. Learn. 10 (2), 206–210. https://doi.org/10.1016/j.cptl.2017.10.001.

Grady, S.E., 2011. Team-based learning in pharmacotherapeutics. Am. J. Pharm. Educ. 75 (7) https://doi.org/10.5688/ajpe757136 (Article 136).

Haidet, P., Kubitz, K., Mccormack, W.T., 2014. Analysis of the team-based learning literature: TBL comes of age. J. Excell. Coll. Teach. 25 (3–4), 303–333.

Interprofessional Education Collaborative. (2023). IPEC Core Competencies for Interprofessional Collaborative Practice: Version 3. Washington, DC: Interprofessional Education Collaborative.

Joanna Briggs Institute. (2020). *Critical appraisal tools.* https://jbi.global/critical-appraisal-tools.

Johnson, J.F., Bell, E., Bottenberg, M., Eastman, D., Grady, S., Koenigsfeld, C., Maki, E., Meyer, K., Phillips, C., Schirmer, L., 2014. A multiyear analysis of team-based learning in a pharmacotherapeutics course. Am. J. Pharm. Educ. 78 (7) https://doi.org/10.5688/ajpe787142 (Article 142).

Joshi, T., Budhathoki, P., Adhikari, A., Poudel, A., Raut, S., Shrestha, D.B., 2022. Team-based learning among health care professionals: a systematic review. Cureus 14 (1). https://doi.org/10.7759/cureus.21252 (Article e21252).

Kelly Orr, K., Feret, B.M., Lemay, V.A., Cohen, L.B., mac Donnell, C.P., Seeram, N., Hume, A.L., 2015. Assessment of a hybrid team-based learning (TBL) format in a required self-care course. Curr. Pharm. Teach. Learn. 7 (4), 470–475. https://doi.org/10.1016/j.cptl.2015.04.016.

Kurup, S., Jungsuwadee, P., Sakharkar, P., 2017. A team-based assignment to integrate basic science and pharmacotherapeutic principles for anticancer agents. Am. J. Pharm. Educ. 81 (5), Article 93. https://doi.org/10.5688/ajpe81593.

Lang, B., Zhang, L., Lin, Y., Han, L., Zhang, C., Liu, Y., 2019. Team-based learning pedagogy enhances the quality of chinese pharmacy education: a systematic review and meta-analysis. BMC Med. Educ. 19 (1) https://doi.org/10.1186/s12909-019-1724-6 (Article 286).

McCartney, J., Boschmans, S.-A., 2020. Evaluation of an intervention to support the development of clinical problem solving skills during a hospital-based experiential learning program for south african pharmacy students. Curr. Pharm. Teach. Learn. 12 (5), 590–601. https://doi.org/10.1016/j.cptl.2020.01.016.

Meng, X., Yang, L., Sun, H., Du, X., Yang, B., Guo, H., 2019. Using a novel student-centered teaching method to improve pharmacy student learning. Am. J. Pharm. Educ. 83 (2) https://doi.org/10.5688/ajpe6505 (Article 6505).

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L.A., 2015. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst. Rev. 4 (1), Article 1. https://doi.org/10.1186/2046-4053-4-1.

Muzyk, A.J., Fuller, S., Jiroutek, M., Grochowski, C.O., Butler, A.C., May, D.B., 2015. Implementation of a flipped classroom model to teach psychopharmacotherapy to third-year doctor of pharmacy (PharmD) students. Pharm. Educ. 15 (1), 44–53.

Ofstad, W., Brunner, L.J., 2013. Team-based learning in pharmacy education. Am. J. Pharm. Educ. 77 (4), Article 70. https://doi.org/10.5688/ajpe77470.

Parmelee, D., Michaelsen, L.K., Cook, S., Hudes, P.D., 2012. Team-based learning: a practical guide: AMEE guide No. 65. Med. Teach. 34 (5), e275–e287. https://doi.org/10.3109/0142159X.2012.651179.

Persky, A.M., Pollack, G.M., 2011. A modified team-based learning physiology course. Am. J. Pharm. Educ. 75 (10) https://doi.org/10.5688/ajpe7510204 (Article 204).

Reimschisel, T., Herring, A.L., Huang, J., Minor, T.J., 2017. A systematic review of the published literature on team-based learning in health professions education. Med. Teach. 39 (12), 1227–1237. https://doi.org/10.1080/0142159X.2017.1340636.

Swanson, E., McCulley, L.V., Osman, D.J., Scammacca Lewis, N., Solis, M., 2019. The effect of team-based learning on content knowledge: a meta-analysis. Act. Learn. High. Educ. 20 (1), 39–50. https://doi.org/10.1177/1469787417731201.

Team-Based Learning^{TM} Collaborative. (n.d.). *Overview*. http://www.teambasedlearning.org/definition/. accessed on 1/2/2023.

Trullàs, J.C., Blay, C., Sarri, E., Pujol, R., 2022. Effectiveness of problem-based learning methodology in undergraduate medical education: a scoping review. BMC Med. Educ. 22 (1) https://doi.org/10.1186/s12909-022-03154-8 (Article 104).

Tweddell, S., 2020. Evaluating the introduction of team-based learning in a pharmacy consultation skills module. Pharm. Educ. 20 (1), 151–157. https://doi.org/10.46542/pe.2020.201.151157.

Wilson, J.A., Waghel, R.C., Free, N.R., Borries, A., 2016. Impact of team-based learning on perceived and actual retention of over-the-counter pharmacotherapy. Curr. Pharm. Teach. Learn. 8 (5), 640–645. https://doi.org/10.1016/j.cptl.2016.06.008.